An Asian Journal of Soil Science
Volume 11 | Issue 2 | December, 2016 | 341-347 | e ISSN–0976–7231 ■ Visit us : www.researchjournal.co.in

Research Article

DOI : 10.15740/HAS/AJSS/11.2/341-347

Influence of lime, zinc and boron on soybean yield and nutrient availability in lateritic soil of Konkan

■ P.K. RATHOD, V.G. SALVI, S.S. PAWAR AND K.N. CHAVAN

Received : 18.09.2016; **Revised :** 30.10.2016; **Accepted :** 23.11.2016

MEMBERS OF RESEARCH FORUM:

Corresponding author :
P.K. RATHOD, Department of Soil Science and Agricultural Chemistry, College of Agriculture, (Dr.BSKKV) Dapoli, RATNAGIRI (M.S.) INDIA

Co-authors :
V.G. SALVI, **S.S. PAWAR AND K.N. CHAVAN,** Department of Soil Science and Agricultural Chemistry, College of Agriculture, (Dr.BSKKV) Dapoli, RATNAGIRI (M.S.) INDIA

Summary

A field experiment was conducted during *Kharif* on lateritic soil of Botany Farm, College of Agriculture, Dapoli in Konkan region of Maharashtra to study the effect of lime, zinc and boron on soybean yield and available nutrients in soil during crop growth. The experiment was laidout in Randomized Block Design with three replications. The treatments consisting two levels of liming *i.e.* ½ LR and 1 LR in combination with soil and foliar application of Zn and B in their combinations. The results of the experiment showed significantly increased the grain (25.52 q ha^{-1}) and straw (37.29 q ha^{-1}) yield of soybean due to application of 1 LR+ Zn +B through soil and foliar spray along with RDF. The available major as well as secondary nutrients at grand growth period and at harvest of soybean significantly recorded highest values of available N, P_2O_5, K_2O and S exchangeable Ca and Mg and available S with treatment RDF +1 LR + Zn and B through soil and foliar spray, closely followed by application RDF +1 LR + B through soil and foliar spray.

Key words : Lime, Zinc, Boron, Soybean, Yield, Available major, Secondary nutrients

How to cite this article : Rathod, P.K., Salvi, V.G., Pawar, S.S. and Chavan, K.N.(2016). Influence of lime, zinc and boron on soybean yield and nutrient availability in lateritic soil of Konkan. *Asian J. Soil Sci.*, **11** (2) : 341-347 : **DOI : 10.15740/HAS/AJSS/11.2/341-347.**

Introduction

The acid soils are characterized by presence of Al, Fe and Mn in soil solution at a toxic level, nutritional imbalance caused due to increase or decrease of the concentration of ions in the soil solution, deficiency of phosphorus, boron, zinc and molybdenum and poor microbiological activity leading to low nitrogen and sulphur availability. Intense leaching due to high rainfall in Konkan region removes major portion of all the bases from the soil giving distinctly acid character. In order to overcome the constraints in the productivity of acid soils, the age old practice is to apply lime judiciously to correct the soil acidity. The use of lime is in no way less important than the application of chemical fertilizers since lime not only furnishes calcium to the plants but also induces greater availability and uptake of other plant nutrients.

The acid soils occupy about 90 million hectares, constituting over one-fourth of total geographical area of the country. The extent of acid soils in Maharashtra is about 0.54 million hectare (Anonymous, 2012). In Maharashtra, soybean is cultivated on 3.22 million ha of area with an annual production of 4.67 million Mt and the productivity is 1,450 kg ha^{-1} (Anonymous, 2013). Soybean is an environment friendly grain legume and has now become a major source of protein, oil and health promoting phytochemicals for human nutrition and livestock feed around the globe. Soybean cultivation also improves soil health because of its atmospheric nitrogen

fixing ability and deep root system. India has a great potential for production and domestic utilization of soybean and its derivatives for health and economic benefits of the people of the country. Although beneficial effects of lime application on various crops in acid soils are well known, the information regarding the effect of B and Zn in presence of lime in legume is not adequate. The potentials of using lime for soils sustainable management are among the other options to explore in restoring soil health and fertility. In agriculture, the limes play a great importance in improving soil acidity and hence favour plant nutrition (Athanase, 2013).

Considering this situation such studies are very much essential in the context of intensive farming approach. Therefore, in the present study an attempt has been made to consider crops other than the rice for their response to lime.

Resource and Research Methods

A field experiment was conducted during *Kharif* season of year 2003 on lateritic soil of Botany Farm, College of Agriculture, Dapoli in Konkan region of Maharashtra to study the influence of lime, zinc and boron on soybean yield and available major and secondary nutrients in soil. The experiment was laidout in Randomized Block Design with three replications and the treatments included two levels of liming *i.e.* ½ LR and 1 LR in combination with soil and foliar application of Zn and B. Lime requirement was determined using buffer solution (1:2) as described by Shoemaker *et al.* (1961). The liming material was obtained as byproduct of Rashtriya Chemicals and Fertilizers Ltd., Mumbai. Soybean var. MACS-13 was grown with 30 x 15 cm and harvested at complete maturity. Treatment wise grain and straw yield data have been expressed in q ha^{-1}. The representative surface soil samples (0-22 cm) were collected from each treatment plot at grand growth and after harvest. The available major and secondary nutrients of soil was analysed by using standard the procedures. Bulk density was determined by clod method as described by Black (1965). The measurement of wet aggregates was carried out with the help of Yoder's apparatus (3/4 inch stroke at 29 stroke per minute) by using 2.0, 1.0, 0.5, 0.25 and 0.106 mm sieves and results were expressed as Mean Weight Diameter (MWD) as described by Singh (1980). Maximum water holding capacity was determined by using Keen-Rackzowski circular brass boxes as described by Piper (1966). The pH and electrical conductivity was estimated by glass electrode pH meter and EC meter, respectively using soil:water suspension 1:2.5 (Jackson, 1973), organic carbon content by wet oxidation using Walkley and Black's titration method (Black, 1965), calcium carbonate by rapid titration method as described by Piper (1966). The available nitrogen was estimated by alkaline $KMnO_4$ method developed by Subbiah and Asija (1956), available phosphorus was extracted by NH_4F-HCl solution and the phosphorus in the extract was determined by spectrophotometer method (Bray and Kurtz, 1945), the available potassium was extracted by shaking with neutral normal ammonium acetate for 5 minutes (Hanway and Heidal, 1952) and potassium in the extract was estimated by flame photometer method (Tandon, 1993). Exchangeable calcium and magnesium were determined by Versenate titration method as given in U.S.D.A. Hand book No. 60 (Anonymous, 1968). Available sulphur in soil was extracted by using Morgan's solution *i.e.* sodium acetate extractant and was determined turbidometrically by using barium chloride on spectrophotometer at 420 nm as described by Chesnin and Yien (1950) and the experimental data was analysed statistically by adopting the method given by Panse and Sukhatme (1967).

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads:

Physico-chemical properties and nutrient status of initial soil :

The soil of the experimental plot was lateritic (Alfisol) and acidic in reaction. It was very high in organic carbon, moderately high in available N, low in available P_2O_5, very high in available K_2O and low in available sulphur. The physico-chemical properties and nutrient status of initial soil sample are presented in Table 1.

These results corroborate the findings of Salvi *et al.* (2015) who reported that the physico-chemical properties and nutrient status of initial soil and sample of lateritic soils in coastal region of Maharashtra.

Yield of soybean :

The data pertaining to the grain and straw yield of soybean as influenced by various treatments is presented in Table 2. It is observed that the grain and straw yield

of soybean were significantly influenced by liming. The lowest value of grain (4.35 q ha^{-1}) and straw yield (10.23 q ha^{-1}) were obtained with absolute control. Recommended dose of NPK fertilizer in combination with lime and micronutrients produced higher yields as compared to control as well as application of chemical fertilizers. Among the various treatments, treatment T_8 (RDF + 1 LR + Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg borax ha^{-1} through soil application+ Zn and B as foliar application @ 0.5% $ZnSO_4$ and 0.1% borax, respectively) produced significantly higher yield as compared to all other treatments, which was followed by treatment T_5 (RDF + 1 LR+ B @ 5 kg borax ha^{-1} through soil application + 1 spray @ 0.1 per cent borax at flowering time). The magnitude of response by soybean was more in case of boron than zinc. These results suggest mutual synergism between Zn and B. Such synergistic effect of Zn on B on grain and straw yield of soybean was obtained by Malewar *et al.* (2001). The treatment T_5 has showed its superiority over T_4, which produced 21.20 q ha^{-1} grain yield and 31.27 q ha^{-1} straw yield. Shankhe *et al.* (2004) reported that foliar application of boron @ 0.5 % borax + soil application of molybdenum @ 1 kg ha^{-1} with RDF resulted in highest kernel and straw yield of groundnut. Subramanian *et al.* (2005) attributed application of Zn + S + B + Mo @ 5 kg + 40 kg + 1.5 kg + 0.5 kg, respectively recorded highest grain yield. The highest grain yield (22.65 q ha^{-1}) and straw yield (19.66

Table 1 : Physico-chemical properties and nutrient status of initial soil

Sr. No.	Characteristics	Initial soil
1.	Bulk density (Mg m^{-3})	1.45
2.	Mean weight diameter (mm)	1.52
3.	Maximum water holding capacity (%)	57.17
4.	pH	5.23
5.	Electrical conductivity (dS m^{-1})	0.165
6.	Organic carbon (g kg^{-1})	17.7
7.	Calcium carbonate (%)	0.42
8.	Exchangeable calcium [cmol(p^+)kg^{-1}]	4.43
9.	Exchangeable magnesium [cmol(p^+)kg^{-1}]	2.77
10.	Available nitrogen (kg ha^{-1})	467.33
11.	Available phosphorus (kg ha^{-1})	8.30
12.	Available potassium (kg ha^{-1})	484.21
13.	Available sulphur (mg kg^{-1})	9.65

Table 2 : Effect of application of lime, zinc and boron on grain and straw yield of soybean

Tr. No.	Treatments details	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1	Control (No fertilizer and no lime)	4.35	10.23
T_2	RDF (Recommended dose of fertilizer)	9.18	17.83
T_3	RDF + 1 LR (lime requirement)	15.65	23.96
T_4	RDF + 1 LR + Zn @ 20 kg $ZnSO_4$ ha^{-1} through soil + 1 spray @ 0.5% $ZnSO_4$ at flowering time	16.03	24.14
T_5	RDF + 1 LR B @ 5 kg borax ha^{-1} through soil application + 1 spray @ 0.1% borax at flowering time	21.20	31.27
T_6	RDF + ½ LR + Zn @ 20 kg $ZnSO_4$ ha^{-1} through soil + 1 spray @ 0.5% $ZnSO_4$ at flowering time	15.36	23.35
T_7	RDF + ½ LR B @ 5 kg borax ha^{-1} as soil application @ 0.1% borax at flowering time	21.05	30.99
T_8	RDF + 1 LR+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg borax ha^{-1} through soil application+ Zn and B as foliar application @ 0.5% $ZnSO_4$ and 0.1 % borax, respectively	25.52	37.29
T_9	RDF + ½ LR+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg borax ha^{-1} through soil application+ Zn and B as foliar application @ 0.5% $ZnSO_4$ and 0.1% borax, respectively	20.95	30.63
	S.E.±	0.74	1.01
	C.D.(P=0.05)	2.21	3.02

q ha^{-1}) was observed by Sale and Nazirkar (2013) due to application of foliar spray of zinc and iron in combination.

Effect on available nutrients :

Available nitrogen:

Available nitrogen content of soil as influenced by different treatments at grand growth stage and at harvest of soybean is presented in Table 3. From the data, it is evident that the available nitrogen content of soil at grand growth period of soybean varied from 395.02 to 470.77 kg ha^{-1}. The treatment control (T_1) showed the lowest content of available nitrogen in the soil. While significantly highest available nitrogen was observed with treatment T_8 *i.e.* combined application of RDF, Zn + B with full dose of lime followed by treatment T_5 and T_7 containing RDF + Lime and B application. Further, there was rise in available nitrogen in the soil with increased dose of lime application indicating favourable effect of lime and boron on availability of nitrogen in soil. The available nitrogen however, reduced at harvest of soybean. Combined application of Zn and B along with RDF and full dose of lime resulted in significantly highest available nitrogen over rest of the treatments followed by treatment T_5 and T_4. The same trend was observed at grand growth stage. The reasons for obtaining these findings are attributed to the indirect effect of enhanced soil pH and direct effect of accelerated rate of mineralization of organic matter due to increased biological activity of soil micro-organisms. The results were in conformity with the findings of Khoi *et al.* (2010) who reported that application of lime at the rate 80 mg/ 20 g soil in combination with 1.25 g compost increased the nitrogen content in soil.

Available phosphorus :

Available phosphorus (Table 3) in the experimental plot was lowest in control *i.e.* 6.87 kg ha^{-1} at grand growth period of soybean and highest was 13.67 kg ha^{-1} due to the application of RDF + 1 LR + Zn + B (T_8). The available phosphorus content raised significantly due to application of NPK at recommended dose over control. Combined application of treatment T_8 (*i.e.* RDF + 1 LR + Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg borax ha^{-1} through soil application + Zn and B as foliar application @ 0.5 % $ZnSO_4$ and 0.1 % borax) recorded highest available phosphorus *i.e.* 13.67 kg ha^{-1} which was significantly superior over rest of the treatments followed by T_5 and T_4. The available phosphorus content in soil however improved after harvest of soybean. It may be the effect of liming in acid lateritic soil. From the above data, it is confirmed that nutrient status of soil is favourably affected by cultivation of legume crops. The increase in available P content of soils due to liming may be attributed to the release of native P, solubalization of Fe and Al bound P as a result of increase in OH ion concentration and precipitation of active Fe and Al into their insoluble forms of hydroxides and thereby decreasing their activity in soil solution. It may also be due to greater microbiological activity at the favourable pH for rapid mineralization of organic matter. These results corroborate with the findings of Osundwa *et al.* (2013) who recorded that the soil available phosphorus increased with increase in the rate of lime addition.

Table 3: Effect of application of lime, zinc and boron on available major and secondary nutrients in soil at grand growth stage and after harvest of soybean

Tr. No.	N (kg ha^{-1})		P_2O_5 (kg ha^{-1})		K_2O (kg ha^{-1})		Ca (cmol(p^+) kg^{-1})		Mg (cmol(p^+) kg^{-1})		S (mg kg^{-1})	
	GR*	AH**	GR	AH	GR	AH	GR	AH	GR	AH	GR	AH
T_1	395.02	361.23	6.87	6.70	459.92	369.16	4.39	4.20	2.74	2.60	6.40	6.05
T_2	427.23	384.83	8.27	8.84	511.88	377.49	5.17	4.83	2.93	2.76	7.71	8.88
T_3	438.83	395.96	8.89	9.48	538.43	380.68	5.79	5.31	3.91	3.68	7.86	9.04
T_4	446.64	395.96	10.85	11.42	550.40	385.28	8.20	7.56	5.41	5.14	10.01	11.58
T_5	466.18	397.42	12.32	13.76	582.78	389.87	9.30	8.64	5.73	5.41	8.34	9.47
T_6	438.91	386.38	10.06	10.05	538.11	378.34	6.22	5.80	4.48	4.19	8.66	9.94
T_7	459.70	390.96	10.29	10.73	575.45	388.08	7.54	6.88	5.18	4.87	8.01	9.22
T_8	470.77	405.51	13.67	17.25	601.93	393.35	10.89	9.99	5.99	5.48	9.22	10.67
T_9	449.47	387.14	9.85	10.18	558.89	383.37	6.98	6.54	4.83	4.51	8.46	9.72
S.E.$\pm$	1.26	2.37	0.23	0.41	2.04	2.00	0.13	0.14	0.05	0.05	0.18	0.24
C.D.(P=0.05)	3.79	7.12	0.68	1.22	6.10	6.01	0.40	0.43	0.16	0.14	0.54	0.72

*GR= Grand growth **AH=After harvest

Available potassium :

Available potassium in the soil at grand growth period of soybean was lowest in absolute control being 459.92 kg ha^{-1} and it was highest being 601.93 kg ha^{-1} in T_8 (Table 3). The treatment T_8 *i.e.* RDF + 1 LR+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg borax ha^{-1} through soil application + Zn and B as foliar application @ 0.5% $ZnSO_4$ and 0.1 per cent borax was found significantly superior over all other treatments followed by T_5 and T_7. The values of available potassium however, reduced after harvest of soybean. From the data, it is observed that available potassium of soil after harvest of soybean varied between 369.16 to 393.35 kg ha^{-1}. The effect of recommended dose of NPK treatment on increasing available potassium status of soil was observed to be statistically significant over the control. The trend remained the same as that of grand growth stage. The increase in available potassium status of soil due to liming and micronutrient may be explained on the basis of acceleration in the release of potassium from non-exchangeable fraction to available pool. The above results corroborate the findings of Vyas *et al.* (2003) who reported that soil available potassium increased due to application of Zn or B with FYM significantly over control.

Exchangeable calcium :

A perusal of data reveals that there were significant differences in exchangeable calcium content of soil during both the stages *i.e.* at grand growth and after harvest of soybean (Table 3). Lowest exchangeable calcium 4.39 and 4.20 cmol(p+) kg^{-1} was observed in control (T_1) during grand growth period and after harvest, respectively. There was increase in the exchangeable calcium content of soil due to application of full dose of lime as in treatment T_8, T_5 and T_4. Addition of Zn and B further increased the exchangeable calcium content of soybean both at grand growth as well as at harvest. The corresponding increase in calcium content of soil with increased dose of lime with Zn and B might be due to the application of calcium through a source of lime (39% Ca) resulting into calcium saturation of exchangeable complex of kaolinite clay minerals which are dominant in lateritic soil of Konkan. Highest exchangeable calcium content [10.89 cmol(p+)kg^{-1}] at grand growth stage in soil was recorded in the treatment (T_8) receiving RDF + 1 LR+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg borax ha^{-1} (soil) + Zn and B (foliar) @ 0.5% $ZnSO_4$ and 0.1 % borax, respectively followed by T_5, T_4, T_7, T_9, T_6, T_3 and treatment T_2, respectively. The exchangeable calcium content of soil after harvest of soybean was reduced in all the treated plots. Similar trend as in grand growth stage was observed for exchangeable calcium content of soil after harvest of soybean. The increase in exchangeable calcium was in direct proportion with increase in lime level and addition of Zn or B or both. The increase in charge density due to liming has greater affinity for high valent ions. Thus, calcium being divalent cation and its higher solution concentration due to liming might have increased its concentration on exchangeable complex. Similar results are also obtained by Suresh and Suryaprabha (2005) who reported the synergetic effect of combined application of NPK with Zn, Cu and B on exchangeable calcium. These results corroborate the findings reported by Athanase (2013).

Exchangeable magnesium :

The data regarding exchangeable magnesium status in soil at grand growth period and after harvest of soybean are presented in Table 3. The perusal of data revealed that there were significant differences in exchangeable magnesium content of soil. Application of recommended NPK was responsible for significant increase in exchangeable magnesium content in soil. Exchangeable magnesium raised due to liming with NPK at recommended doses and was significantly superior over absolute control during grand growth of soybean. The treatment T_8 (RDF + 1 LR+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg borax ha^{-1} through soil application and Zn and B as foliar application @ 0.5% $ZnSO_4$ and 0.1 % borax, respectively) was found significantly superior over all the other treatments. Exchangeable magnesium of the soil tended to increase with increase (doubled) in lime application along with N, P, K, Zn and B, respectively. After harvest of soybean the exchangeable magnesium content in soil was depleted in all the treated plots. However, the trend remained the same as in grand growth stage. Lime application with NPK also recorded significant higher magnesium. The treatment T_8 recorded significantly highest exchangeable magnesium content in soil over all other treatments except T_5 indicating that B application along with lime and RDF is more effective in increasing exchangeable magnesium in soil than Zn application. The corresponding increase in exchangeable magnesium content of soil with N, P, K, Zn, B along with increasing levels of lime is due to higher base saturation

of the exchange complex and addition of magnesium through liming material containing 0.2 per cent magnesium. These results are in agreement with the findings of Athanase (2013), who reported that the exchangeable magnesium increased with application of lime.

Available sulphur :

It is observed that available sulphur (Table 3) in the soil at grand growth period of soybean varied between 6.40 to 10.01 mg kg^{-1}. Maximum increase (10.01 mg kg^{-1}) in available sulphur was observed due to treatment T_4 *i.e*. RDF + 1 LR+ Zn @ 20 kg $ZnSO_4$ ha^{-1} through soil application + 1 spray @ 0.5% $ZnSO_4$ at flowering and proved its superiority over all other treatments. This significant improvement regarding available sulphur content in soil may be because of addition of zinc sulphate containing 11.15 per cent sulphur. It was followed by T_8. Similar trend was observed in respect of available sulphur content in soil after harvest of soybean. Significant improvement was observed in available sulphur status of soil after harvest of soybean. The increase in the available sulphur may be due to the amount of sulphate (SO_4^{3-}) released slowly with increase in lime dose, which is attributed to the increase in the rate of mineralization of organic matter due to liming and/or due to increase in salinisation of sparingly soluble sulphate compounds which have been postulated to be present in acid soils of Konkan. The above results are in conformity with the findings of Chavan (1999) who observed that the micronutrient application along with sulphur increased the available sulphur content of soil.

Conclusion :

Among the various treatments, treatment T_8 (RDF + 1 LR+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg borax ha^{-1} through soil application+ Zn and B as foliar application @ 0.5% $ZnSO_4$ and 0.1 % borax, respectively) produced significantly higher yield as compared to all other treatments, which was followed by treatment T_5 (RDF + 1 LR + B @ 5 kg borax ha^{-1} through soil application + 1 spray @ 0.1 % borax at flowering time). The magnitude of response by soybean was more in case of boron than zinc. The available NPK and exchangeable Ca + Mg and available S content of soil was significantly increased by the application of lime, zinc and boron along with recommended dose of fertilizers (RDF). The available sulphur content was increased significantly due to application of RDF + 1 LR + Zn through soil and foliar spray followed by application of RDF + 1 LR + Zn + B Through soil and foliar application.

Literature Cited

Anonymous (1968). Diagnosis and improvement of saline and alkali soils, *Handbook of agriculture*, No. 60, U.S.D.A., Washington,pp.94.

Anonymous (2012). *Soil acidity, fundamentals of soil science*, IInd Ed. (Revised), February, 2012, pp: 322-323.

Anonymous (2013). Area, production and yield of soyabean during 2011-12 and 2012-13 in major producing States, Department of Agriculture and Co-operation.

Athanase N. (2013). Soil acidification and lime quality: Sources of soil acidity, effects on plant nutrients, efficiency of lime and liming requirements., Research and Reviews: *J. Agric. & Allied Sci*., **2**(4) : 28-34.

Black, C.A. (1965). *Methods of soil analysis*. Part-II Ame. Soc. Agron. Inc. Madison, Wisconsin, U.S.A. 1040-1041, 1374-1375.

Bray, R.H. and Kurtz, L.T. (1945). Determination of total organic and available form of phosphorus in soil. *Soil Sci*., **59**: 39-44.

Chavan, V.D. (1999). Effect of potassium, sulphur and micronutrients under water stress on yield and uptake of nutrients by mustard (*Brassica juncea* L.) on lateritic soil of Konkan. M.Sc. (Ag.) Thesis, Konkan Krishi Vidyapeeth, Dapoli, dist. Ratnagiri, M.S. (INDIA).

Chesnin, L. and Yien, C.H. (1950). Turbidimetric determination of available sulphur. *Soil Sci. Soc. Amer. Proc.*, **15**: 149-151.

Hanway, J.J and Heidel, H. (1952). Soil analysis methods as used in Iowa State, College soil testing laboratory, *Iowa Agric.*, **54** : 1-131.

Jackson, M.L. (1973). *Soil chemical analysis*. Prentice Hall of Indian Pvt. Ltd., New Delhi, pp. 134-182.

Khoi, C.M., Guong, V.T., Trung , P.N.M. and Nilsson, S.I. (2010). Effect of compost and lime amendment on soil acidity and N availability in acid sulphate soil., 19th World congress of soil science, soil solution for a changing world, held during 1-6 August, 2010 at Brisbane, Australia.

Malewar, G.U., Kate, S.D., Waikar, S.L. and Syed, Ismail (2001). Interaction effects of zinc and boron on yield, nutrient uptake and quality of mustard (*Brassica juncea* L.) on a *Typic Haplustert*. *J. Indian Soc. Soil Sci*., **49**(4): 763-765.

Osundwa, M.A., Okalebo, J.R., Ngetich, W.K., Ochuodho, J.O., Othieno, C.O., Langat, B. and Omenyo, V.S. (2013). Influence of agricultural lime on soil properties and wheat

(*Triticum aestivum* L.) yield on acidic soils of Uasin Gishu County, Kenya. *Amer. J Experimental Agric.*, **3**(4):806-823.

Panse, V.G. and Sukhatme, P.V. (1967). *Statistical methods for agricultural workers*, ICAR, NEW DELHI, INDIA.

Piper C.S. (1966). *Soil and plant analysis*, India. Asian Reprint, Hans Publisher Mumbai, M.S (INDIA).

Sale, R.B. and Nazirkar, R.B. (2013). Response of soybean [*Glycine max* (L.) Merill.] yield, nutrient uptake and quality to micronutrients (Zn, Fe and Mo) under Khandesh region of Maharashtra. *Asian J. Soil Sci.*, **8**(2):245-248.

Salvi, V.G., Bagal, Minal, Bhure, S.S. and Khanvilkar, M.H. (2015). Effect of integrated nutrient management on soil fertility and yield of okra in coastal region of Maharashtra. *Asian J. Soil Sci.*, **10**(2):201-209.

Shankhe, G.M., Naphade, P.S., Rawankar, H.N., Sarup, P.A. and Hadole, S.S. (2004). Effect of boron and molybdenum on their uptake and yield of groundnut. *Agric. Sci. Digest.*, **24**(1): 51-53.

Shoemaker, H.E., McLean, E.O. and Pratt, P.F. (1961). Buffer methods for determining lime requirement of soils with appreciable amounts of extractable aluminium. *Proc. Soil. Sci. Soc. Ame.*, **25**(4): 274-277.

Singh, R.A. (1980). *Soil physical analysis*, Kalyani Publishers, New Delhi-Ludhiana, PUNJAB (INDIA).

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the estimation of available nitrogen in soil. *Curr. Sci*. **25**(8): 259-260.

Subramanian, K.S., Poongothai, S., Chitdeshwari, T. and Duraisami, V.P. (2005). Nutritional and yield responses of blackgram to multi-ecological zone of Tamil Nadu. *Crop Res*., **29**(3): 406-410.

Suresh, S. and Suryaprabha, A.C. (2005). Influence of liming and nutrients on the changes in pH, nutrient availability and yield of wet land banana in a flooded valley Fe toxic soil. *Internat. J. Agric. Sci.*, **1**(1):65-68.

Tandon, H.L.S. (1993). *Methods of analysis of soil, plant, water and fertilizers*. FDCO, New Delhi, India, pp.24-30, 58-62.

Vyas, M.D., Jain, A.K. and Tiwari, R.J. (2003). Long-term effect of micronutrient and FYM on yield of and nutrient uptake by soybean on a *Typic Chromustert*. *J. Indian Soc. Soil Sci*., **51**(1): 45-47.